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HOST, SYNONYMY, AND PARASITIC INCIDENCE OF *BOPYRELLA CALMANI* (RICHARDSON) FROM CENTRAL CALIFORNIA (ISOPODA: EPICARIDEA: BOPYRIDAE)

Clay Sassaman, George A. Schultz, and Ronald Garthwaite

Abstract.—*Bopyrella calmani* (Richardson) has been frequently collected along the central California coast, commonly as a branchial parasite of the snapping shrimp *Synalpheus lockingtoni* Coutière. *Bopyrella macginitiei* Shiino is considered a junior synonym of *B. calmani.* The type-host of *B. calmani,* not previously identified, is most probably an ovigerous female among the syntypes of *S. lockingtoni.* Information on parasite-host interactions between *B. calmani* and *S. lockingtoni* is presented. The natural history of this interaction differs in several aspects from that previously reported in many other bopyrid-shrimp interactions.

Two species of *Bopyrella* Bonnier have been described from the eastern Pacific Ocean, both from the Channel Islands off southern California. *Bopyriscus calmani* Richardson (1905) was described from a single female (with attached male) collected off San Nicholas Island at *Albatross* station 4421. The identity of the host was not recorded in the original description. Bourdon (1980) redescribed the holotype female and allotype male (USNM 32073) and placed the species in *Bopyrella.* He listed the host as *Alpheus* sp. on the basis of a U.S. Fish Commission label contained with the type-material. *Bopyrella macginitiei* Shiino (1964) was described from two females (neither with males) collected off Santa Cruz Island. Both individuals were branchial parasites of the snapping shrimp *Alpheopsis equidactylus* (Lockington).

Individuals of the snapping shrimp *Synalpheus lockingtoni* Coutière (1909) parasitized by a species of *Bopyrella* have been regularly encountered in wharf fouling communities in Monterey Bay, California. Additional parasitized specimens have been collected along other parts of the central California coast. Studies on a series of 36 female isopod parasites (31 with attached males) indicate that there is sufficient morphological variability among these isopods to consider *B. macginitiei* a junior synonym of *B. calmani.* The discovery of *B. calmani* as a parasite of *S. lockingtoni* prompted a search for the type-host of the isopod. Evidence is presented that the host of the type-specimen of *B. calmani* is an ovigerous female discovered among the syntypes of *S. lockingtoni,* which also were collected at *Albatross* station 4421. Aspects of the general biology of *B. calmani* and its parasitic interaction with *S. lockingtoni* are briefly discussed.

Bopyrella calmani (Richardson)
Figs. 1A–H, 2A–F

Bopyriscus calmani Richardson, 1905:562–563, figs. 617–619.—Shiino, 1949: 49.—Danforth, 1963:7, 38–39, pl. 6, figs. 1–2.—Schultz, 1969:336, fig. 543.—Danforth, 1970:10, 44, 65–66, 150, fig. 13d–e.—Wallerstein, 1980:235.

Bopyrella macginitiei Shiino, 1964:22–24, fig. 2a–c.—Schultz, 1969:332, fig. 534c.—Danforth, 1970:9, 43, 60, 151, fig. 7a–b.—Bourdon, 1980:227, 229–230.—Wallerstein, 1980:235.

Bopyrella calmani (Richardson).—Bourdon, 1980:185, 187, 225–227, 229–230, fig. 17a–c.

Female.—Body axis bent to right or left (18 individuals each). Eye spots present. Body surface generally smooth. Length-width ratio about 1–0.65 to 1–0.75. Cephalon with slightly sinuate frontal margin set slightly in front of anterior border of peraeonal segment I and separated from it only by short lateral notches. Lateral process on anterolateral corner of cephalon usually on short side of body only. Maxilliped with setose palp, setae primarily terminal in larger specimens; extending toward inner margins of maxilliped in small specimens. Posterior border of cephalon (ventral view) slightly indented in midline and with 2 lateral projections on each side smoothly tapering to point. Posterior part of first oostegite with posterolaterally directed thin lobe. Internal ridge of first oostegite smooth medially; rough to tuberculate laterally. All pairs of oostegites on both sides with row of setae on posterior borders. Setae long and organized into well-developed setal fringe only on oostegite pair 5.

Body widest at peraeonal segments II and III. Coxal bosses strongly indicated on segments I–IV, lateral plates usually indicated on segments II–IV of expanded side and I–IV of shorter side. Outer surface of basis of peraeopods of longer side with shieldlike expansion and row of teeth on posterior border. Marginal tubercles posterior to peraeopods V–VII on longer side. Pleon with variable configuration: indications of complete sulci between segments on expanded side in some specimens; only partial marginal separation on edges of others. Marginal segmentation only slightly to moderately indicated on shorter side. (Pleonal segments well separated on both sides in immature females.) Pleotelson entirely set within curves of pleonal segment 5. Biramous oval to oblong pleopods with endopod larger than exopod in first pair, ratio changing progressively so that exopod longer than endopod in last 2 or 3 pairs. (Male adheres to open area between pleopods of female.) Immature females with all endopods longer than exopods. Uropods absent.

Male.—Small dark pigment spots as eyes. Frontal margin ranging from slightly concave to slightly convex. Dorsal surface of male (SEM) with slitlike depressions near posterior border of cephalon (over eyes); additional pair of pits on anterior part of cephalon. Antenna 1 with 3 articles. Antenna 2 with 2 articles, both covered with scales. Generally with peraeonal segments I–VII free (in several individuals segment I broadly fused to cephalon). All peraeonal segments with rounded lateral margins; peraeopods subequal in size. Peraeopods with moderately well developed dactyli; patches of scales on inner surfaces of each merus and propodus, sometimes on carpus. Pleon with 3 large free segments, with additional one partially indicated by grooves on pleotelson. In smallest male, pleon with 4 free segments with fifth indicated on pleotelson. Four pairs of pleopods (as oval swellings) on ventral surface of pleotelson (SEM). Underside of anal cone covered with scales, upper surface smooth. Uropods absent.

Measurements.—Holotype female 5 mm long by 3 mm wide; attached male 1.1 mm long (Richardson 1905). Other females to 8.0 mm long; males to 2.2 mm

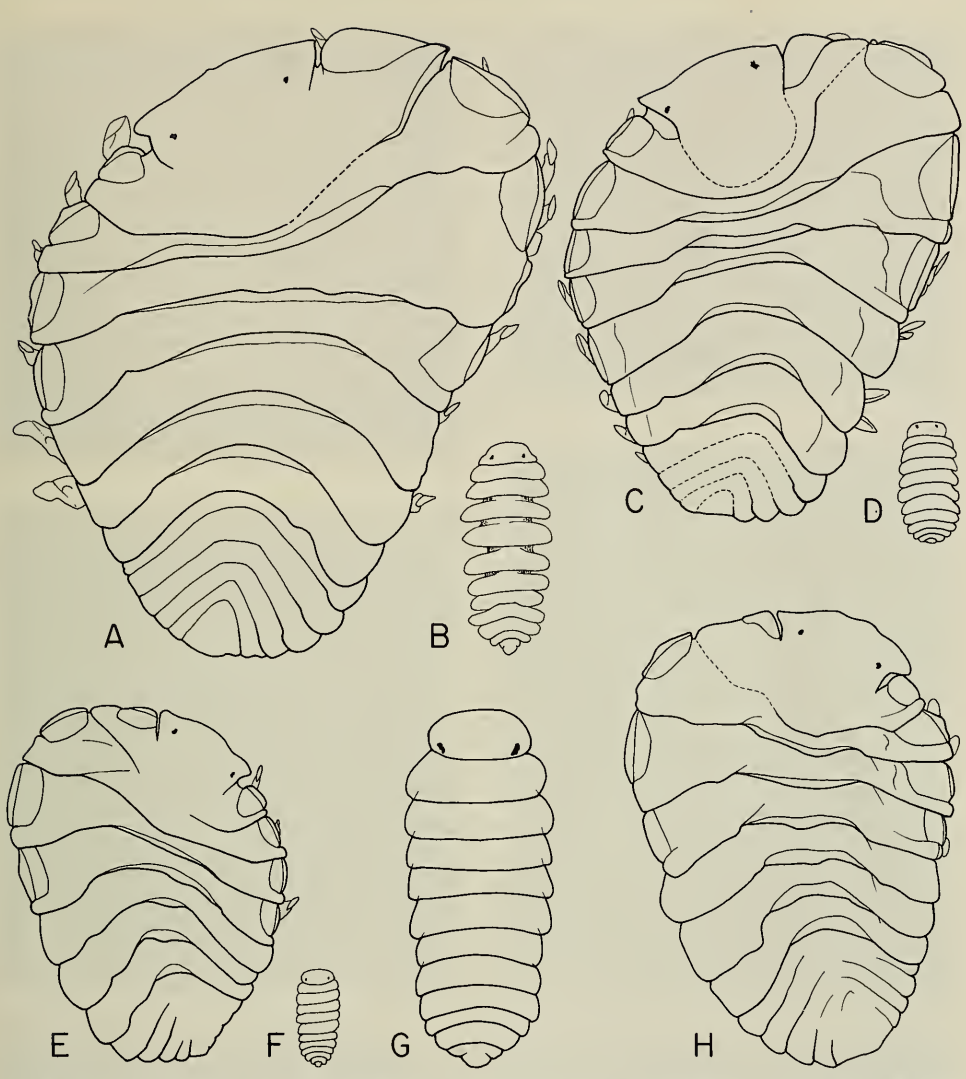

Fig. 1A–H. *Bopyrella calmani*: A, Dextral female 6.3 mm long; B, Male 2.2 mm long from female in A; C, Dextral female 5.0 mm long; D, Male 1.4 mm long from female in C; E, Sinistral female 3.7 mm long; F, Male 1.0 mm long from female in E; G, Projected image of male in F; H, Sinistral female 4.7 mm long.

long. Male length (y) is related to female length (x) by the expression: $y = 0.46 + 0.17\ x$ with high linear correlation ($r = 0.99$).

Type-locality.—*Albatross* station 4421 (Bureau of Fisheries 1906); 12 Apr 1904; 10′ Blake Beam Trawl; 419–545 m; 8 km to southeast of easternmost tip of San Nicholas Island, Channel Islands, California.

Disposition of type-specimens.—The holotype female and allotype male are in the National Museum of Natural History; USNM 32073.

Materials and methods.—Type-specimens in National Museum; 27 females and 23 males from Monterey Bay, California; 9 females and 8 males from Santa

Barbara, California. Three males were examined by scanning electron microscopy—two in ventral and one in dorsal aspect. The ventral surface of one female was also examined. Alcohol-preserved specimens were frozen, lyophilized, and gold-coated prior to examination with a JEOL Stereoscan microscope at 15 Kv. This procedure caused little distortion in males, but much distortion in females. Air-drying after dehydration with alcohol and acetone was generally less satisfactory than lyophilization.

Specimens of the isopods described here (with hosts) have been deposited in the National Museum of Natural History (USNM).

Distribution.—*Bopyrella calmani* has been recorded from San Nicholas Island and Santa Cruz Island in southern California. It has also been collected along the central California coast at Coal Oil Point, Santa Barbara Co., at 11 m; at San Simeon, San Luis Obispo Co., in the lower intertidal zone (P. Van Wyk, U. C. Santa Barbara, pers. comm.); and at Monterey Bay, Monterey Co., at depths of 1–9 m.

Host identity.—The discovery of *Bopyrella calmani* in *Synalpheus lockingtoni* at Monterey suggested that it might also have been the host of the type-specimen. In 1909, Coutière revised the American species of *Synalpheus,* drawing heavily upon those from the *Albatross* collections. He redescribed *S. lockingtoni* on the basis of specimens from *Albatross* station 4421, the type location of *Bopyrella calmani.* Prior to Coutière's redescription, *S. lockingtoni* was known as *Alpheus leviusculus* Lockington; therefore the initial identification of the host of the isopod as *Alpheus* sp. would have been consistent with the nomenclature of the time.

Fortunately the syntypes upon which Coutière based his redescription of the shrimp are in the collections of the National Museum of Natural History (USNM 41738). One of the four specimens (an ovigerous female measuring 5.3 mm from the middle of the eye to the posterior edge of the carapace) has an enlarged left branchial chamber as is typical of a shrimp infected with a bopyrid. The holotype of *B. calmani* is distorted with the characteristic asymmetry of a bopyrid from the left branchial chamber of a shrimp host. The enlarged swelling on the shrimp includes much of the lateral surface of the carapace and some of pleonal segment 1. The swelling measures approximately 4.9 by 2.9 mm, and is in good agreement with Richardson's (1905) measurements of the isopod of 5 by 3 mm. A thin membrane lining the inner surface of the carapace is broken in places and resembles similar material adhering to the ventral surface of the female type-specimen. The shape, location, and texture of the swollen carapace leave little doubt that the ovigerous female of *S. lockingtoni* from the syntype collection is the type-host of *B. calmani.*

Synalpheus lockingtoni is also the host at Santa Barbara, San Simeon, and Monterey. The isopods described by Shiino (1964) were collected from another snapping shrimp, *Alpheopsis equidactylus* (Lockington). *Synalpheus lockingtoni* has been reported from Ecuador to Monterey Bay (Standing 1981). Its depth range is low intertidal to about 530 m (*Albatross* station 4421). *Alpheopsis equidactylus* is reported from the Channel Islands (Shiino 1964) and along the California coast from Palos Verdes to Monterey at depths from the low intertidal to 60 m (Word and Charwat 1976).

Remarks.—There are some substantial discrepancies between the initial description of the holotype of *Bopyrella calmani* (Richardson, 1905) and the sub-

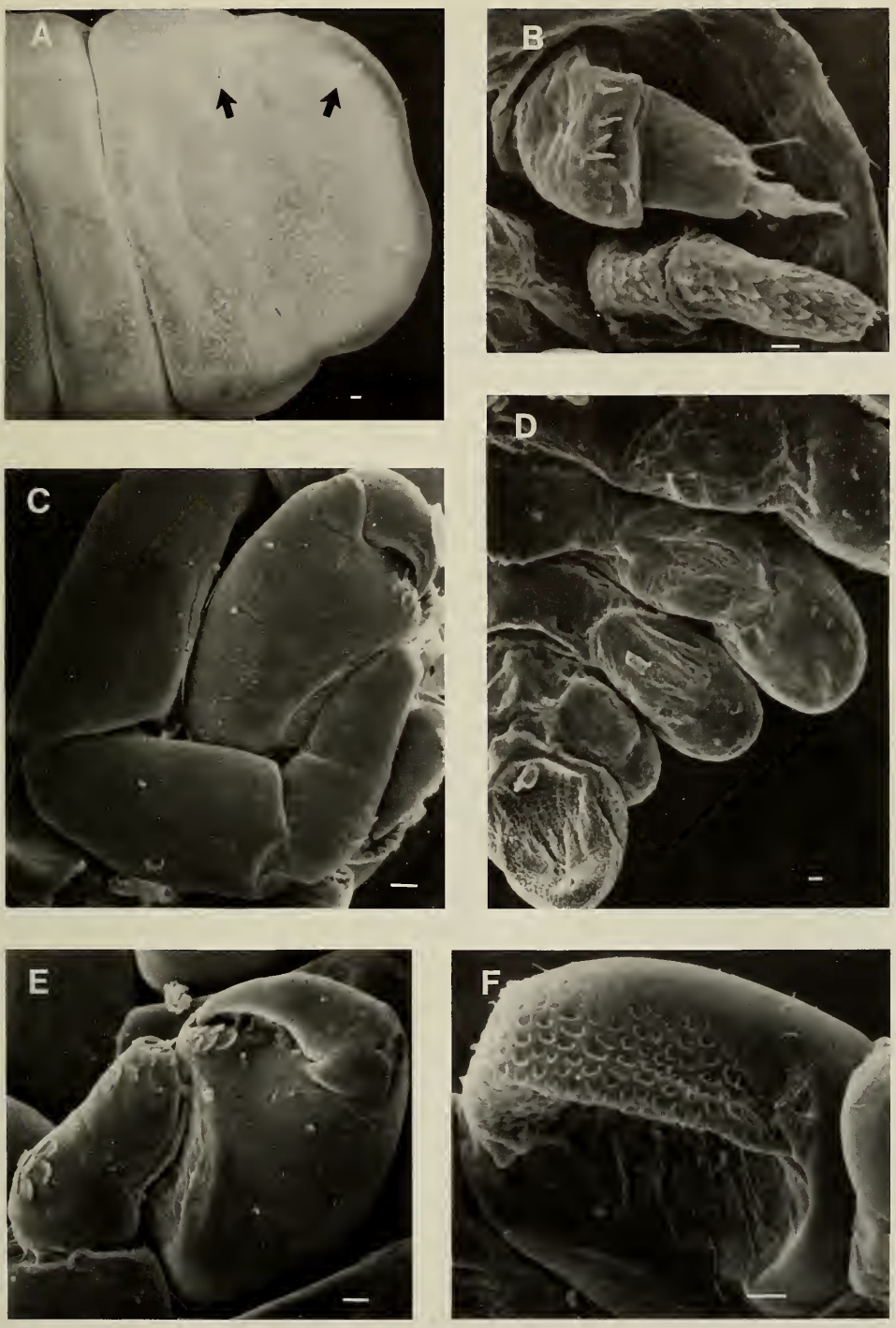

Fig. 2A–F. *Bopyrella calmani,* scanning electron micrographs of the male, scale bars 10 μm: A, Fusion of cephalon and peraeonal segment I, arrows indicate dorsal pits of the left side; B, Ventral view of antennae; C, Peraeopod 7; D, Ventral view of pleopods and anal cone; E, Distal articles of peraeopod 2; F, Ventrolateral view of anal cone.

Table 1.—Incidence of *Bopyrella calmani* in monthly samples of *Synalpheus lockingtoni.*

Location	Date	Number of *S. lockingtoni*	% parasitized by *B. calamani*	Carapace lengths of shrimp (mm)			
				Infected		Uninfected	
				$\bar{x}$	(SD)	$\bar{x}$	(SD)
Monterey Bay	1 Aug 82	30	26.7	7.08	(1.17)	7.00	(1.22)
	12 Nov 82	17	17.6	7.66	(1.97)	6.79	(1.66)
	7 Jan 83	16	6.3	—	—	—	—
	4 Mar 83	31	6.5	—	—	—	—
	29 May 83	52	7.7	6.76	(0.87)	5.57	(2.00)
	10 Sep 83	52	9.6	7.32	(1.08)	5.69	(1.70)
Santa Barbara	4 Dec 82	14	64.3	5.11	(0.63)	4.43	(0.39)

sequent redescription of it by Bourdon (1980). Richardson indicated the presence of eye spots, and figured all the peraeonal segments as free. Bourdon depicted indistinct separation of the peraeonal segments (particularly along the midline), and did not indicate eye spots (although noting their mention in the original description). The two authors also disagree about the extent of separation of the pleonal segments. It is possible that some of the differences between the two descriptions represent artifacts due to the length of storage of the types. Preservation of isopod specimens in alcohol does cause the eye pigment to leach, and in *B. calmani* has led to some differential shrinkage of the female type-specimen. Richardson recorded the holotype as 5 mm long; Bourdon recorded it as 4.2 mm. Furthermore, the body is not closely applied to the cuticle. The differences in description of the peraeonal and pleonal segmentation patterns could be due, in part, to an imperfect alignment of the cuticular pattern of segments relative to the pattern of lines and creases in the underlying tissues. Alternatively (or additionally) some of the discrepancy could be due to differences in interpretation. Our series of specimens (Fig. 1) indicates a great deal of variability associated with the segmentation of both the pleon and peraeon. Some specimens (Fig. 1C) have a partially discernible posterior border to the cephalon, whereas in others (Fig. 1E) the first 2 peraeonal segments are incompletely defined. Similarly a range of variation is present in the degree of separation of the pleonal segments (Fig. 1A, E). In immature females, the lateral borders of the pleon are considerably more symmetric with separations of the edges being distinct on both sides of the body.

For the male, our specimens closely resemble the description of the allotype by Bourdon (1980) with some exceptions. First, although most of the males examined have a free peraeonal segment I, several individuals had the cephalon fused to peraeonal segment I (Fig. 2A). Second, our SEM examinations indicated four pairs of pleopods (Fig. 2D) rather than three pairs as reported by Bourdon (1980). Variation in the shape of males is common (Fig. 1B, D, F). Also immature males have four free pleonal segments rather than three as do typical adult males. Fusion of the pleonal segments apparently occurs during development in males and pleonal segment number is reduced.

In general, however, the specimens of both sexes from Monterey and Santa

Barbara exhibit a range of morphological variation which can easily include the characters of both *B. calmani* and *B. macginitiei.* Accordingly, *B. macginitiei* Shiino (1964) is a junior synonym of *B. calmani* (Richardson, 1905).

Affinities.—*Bopyrella calmani, B. harmopleon* Bowman and Diaz-Ungria, and *B. malensis* Bourdon appear on male and female pleonal characteristics to represent a natural grouping of species within the genus as suggested by Bourdon (1980). All are parasites of snapping shrimps of the genus *Synalpheus*; *B. calmani* is also reported from *Alpheopsis.* Within this grouping, *B. calmani* is closest in morphology to *B. harmopleon,* a species of the western Atlantic Ocean. The principle differences are that in *B. calmani* the body axis is less distorted than in *B. harmopleon,* males of *B. harmopleon* more often have the cephalon fused to peraeonal segment I, and *B. harmopleon* males are reported to lack pleopods (Bowman and Diaz-Ungria 1956; Lemos de Castro 1965).

General Biology

In nine of ten collections made at Monterey, California, between March 1981 and September 1983, specimens of *Synalpheus lockingtoni* parasitized by *Bopyrella calmani* were obtained. Only one sample (January 1982) did not contain any parasitized shrimp. Most parasitized shrimp (26) were removed from wharf fouling communities dominated by the polychaete *Phyllochaetopterus prolifica* Potts collected from Wharf #2 at 1–5 m deep. One was removed from a kelp holdfast from about 9 m deep. The presence of *Synalpheus lockingtoni* itself at Monterey Bay is noteworthy, since only one individual of this shrimp has ever been recorded north of Point Conception (Standing 1981). Two other alpheid shrimps (*Betaeus gracilis* Hart and *Alpheus clamator* Holmes) were collected along with *S. lockingtoni*; neither were infected by bopyrids. A second species of bopyrid, *Aporobopyrus muguensis* Shiino, was common in both the wharf and holdfast communities, being found primarily in the porcellanid crab *Pachycheles rudis* Stimpson and occasionally in *P. pubescens* Holmes.

The incidence of parasitization of *Synalpheus lockingtoni* by *Bopyrella calmani* was monitored from August 1982 to September 1983. The numbers of shrimp and the frequency of parasitism in each collection are given in Table 1. Although the data suggest a possible seasonal pattern of infestation similar to that reported in San Francisco Bay populations of the bopyrid *Argeia pauperata* Stimpson (Gifford 1934), the variation in incidence frequencies is not statistically significant (G-statistic). The average frequency of parasitism for all six samples from Monterey Bay was 12%, which differed significantly from the incidence in a small collection from Santa Barbara in December 1982 (Table 1). Mature female isopods were found in all months sampled, but only the November 1982 and May 1983 collections contained immature individuals. Cryptoniscus larvae were never found.

Bopyrella calmani differentially infected larger individuals of *S. lockingtoni.* In two of the individual collections (December 1982 and May 1983) the average lengths of infected shrimp were significantly greater than those of uninfected ones (Table 1). Two-way analysis of variance of shrimp lengths over all of the collections indicated a highly significant difference, with infected shrimp being larger than uninfected shrimp. No hosts less than 4 mm in carapace length were parasitized. The lengths of mature female isopods were highly correlated with host length (Fig. 3). This correlation did not extend to immature female parasites. They were found

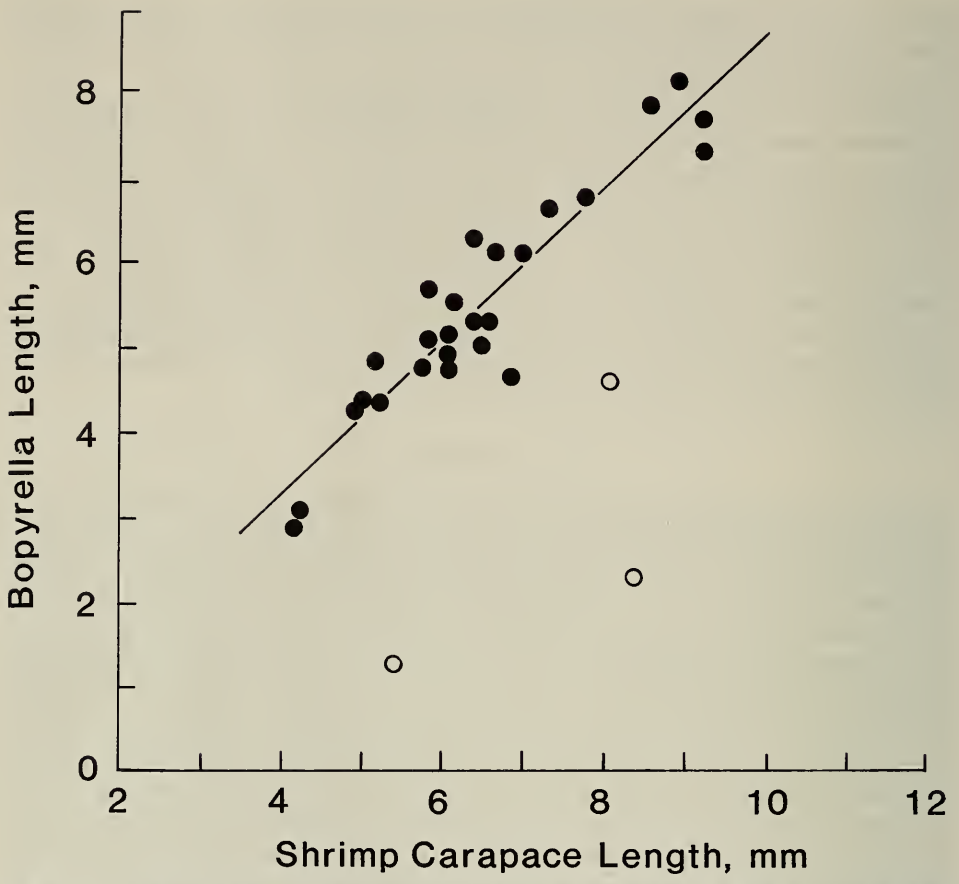

Fig. 3. Correlation between female isopod length and host carapace length. Filled symbols represent mature female isopods, open symbols are immature female isopods.

in large hosts (Fig. 3), suggesting that primary infection by *B. calmani* occurs in relatively large hosts. This pattern is unlike that in many other bopyrid host-parasite systems in which primary infection occurs only in smaller hosts (for review, see Beck 1980).

Brood sizes of *B. calmani* were determined, by direct count, for six gravid females of the August 1982 sample. Brood size averaged 6145, and ranged from 2119 to 13082. Brood size was highly correlated (r = 0.97) with female length, the relationship between brood size (y) and isopod length in mm (x) following the relationship:

$$y = 10.3\ x^{3.47}.$$

The average brood size of *B. calmani* was comparable to that previously reported for other bopyrids of comparable body length (Bourdon 1968; Beck 1980; Truesdale and Mermilliod 1977; Wenner and Windsor 1979).

Bopyrella calmani does not cause parasitic castration of female *S. lockingtoni*. One quarter of all shrimp with brood embryos were parasitized by *B. calmani*.

Van Wyk (1982) has recently reported that although brood size in the crab *Pachycheles rudis* is reduced on parasitization by *Aporobopyrus muguensis,* female reproductive function is not completely destroyed. A similar instance has been reported in *Argeia pugettensis* (Dana), another bopyrid which is common along the Pacific coast (Danforth 1963).

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(CS and RG) Department of Biology, University of California, Riverside, California 92521; (GAS) 15 Smith St., Hampton, New Jersey 08827.